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**Lee et al.**

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(54) **WIRING SUBSTRATE AND DISPLAY DEVICE INCLUDING WIRING SUBSTRATE**

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**G02F 1/1362** (2006.01)  
**H01L 27/12** (2006.01)

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(58) **Field of Classification Search**  
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USPC ..... 257/59, 72  
See application file for complete search history.

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(57) **ABSTRACT**  
A display device may include a first base, a metal oxide layer overlapping a face of the first base, and a conductive metal layer directly contacting the metal oxide layer. The metal oxide layer may include molybdenum oxide. A side of the metal oxide layer may be oriented at a first angle relative to the face of the first base. A side of the conductive metal layer may be oriented at a second angle relative to the face of the first base. A size of the second angle may be in a range of 30° to 75°.

**20 Claims, 12 Drawing Sheets**

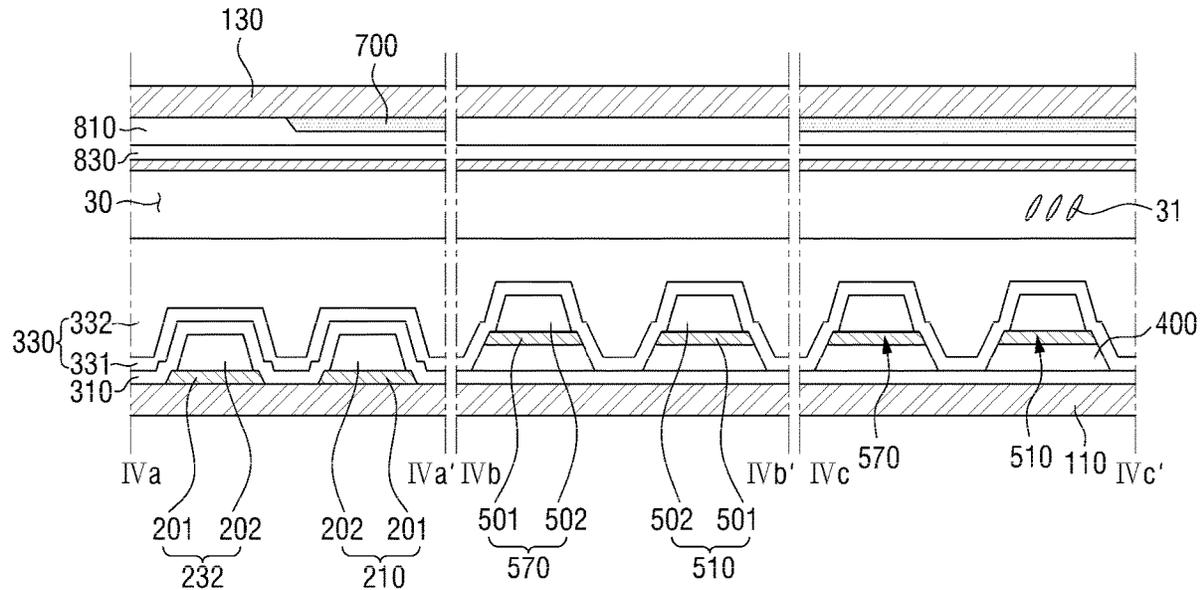


FIG. 1

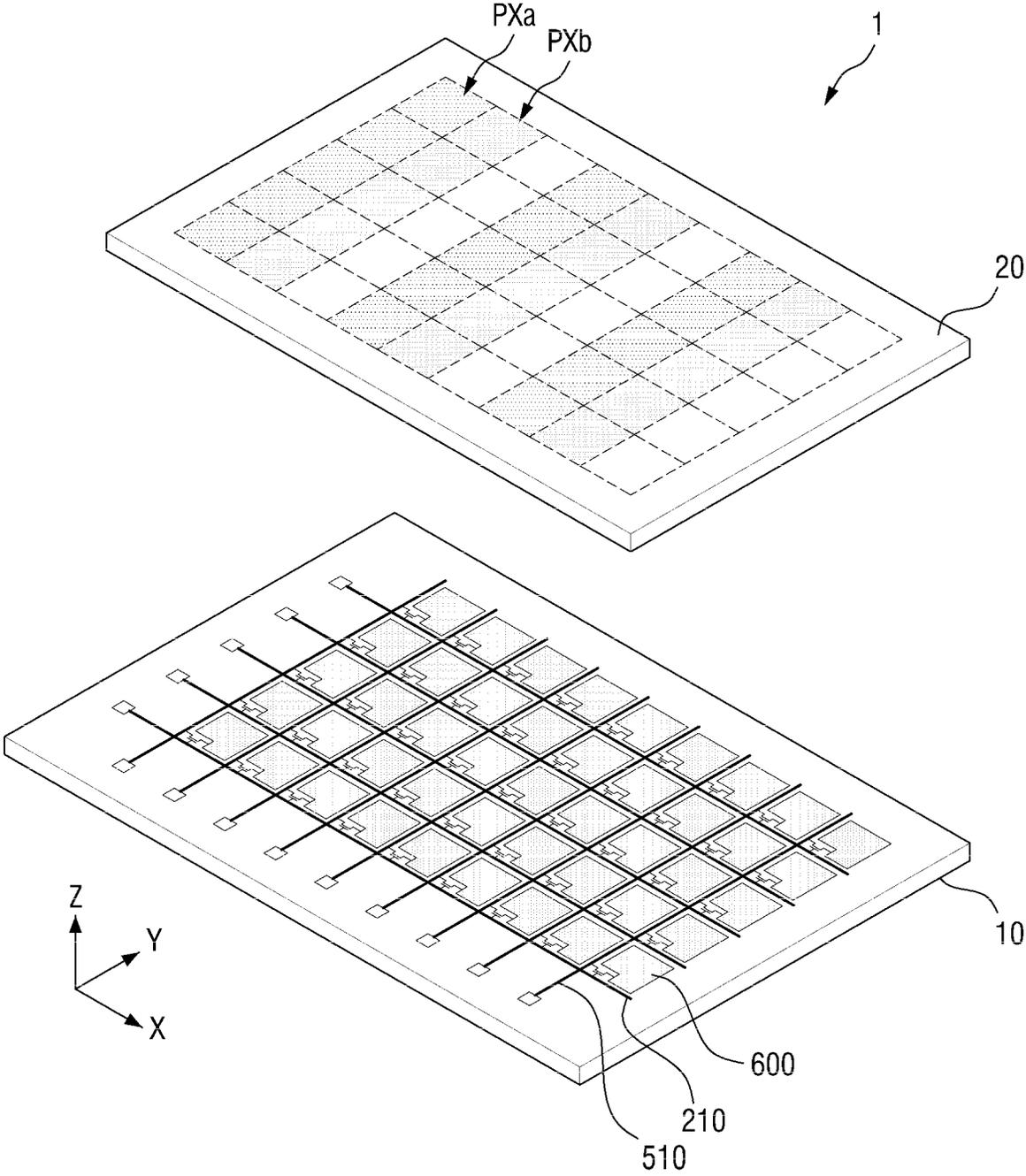


FIG. 2

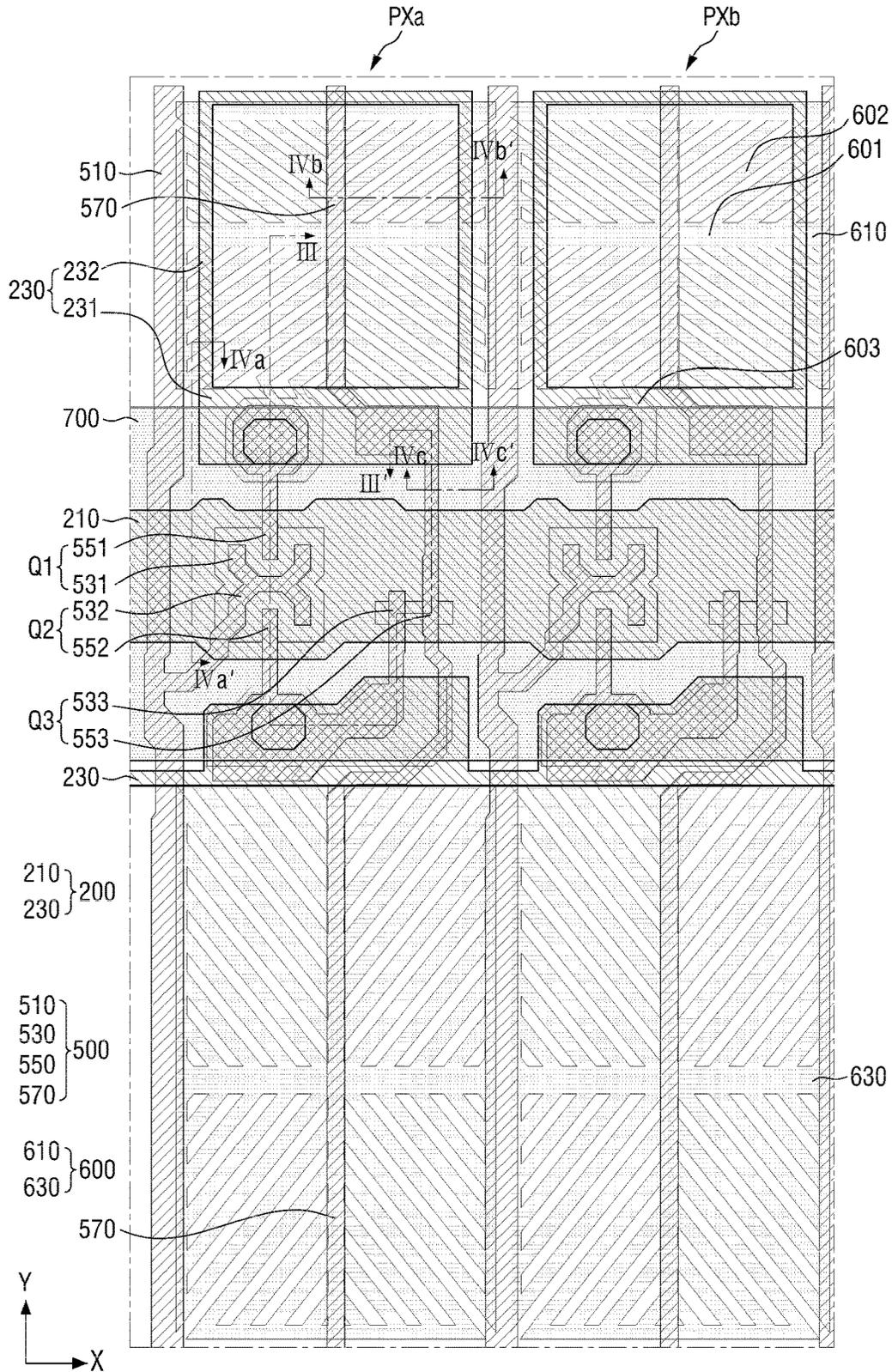


FIG. 3

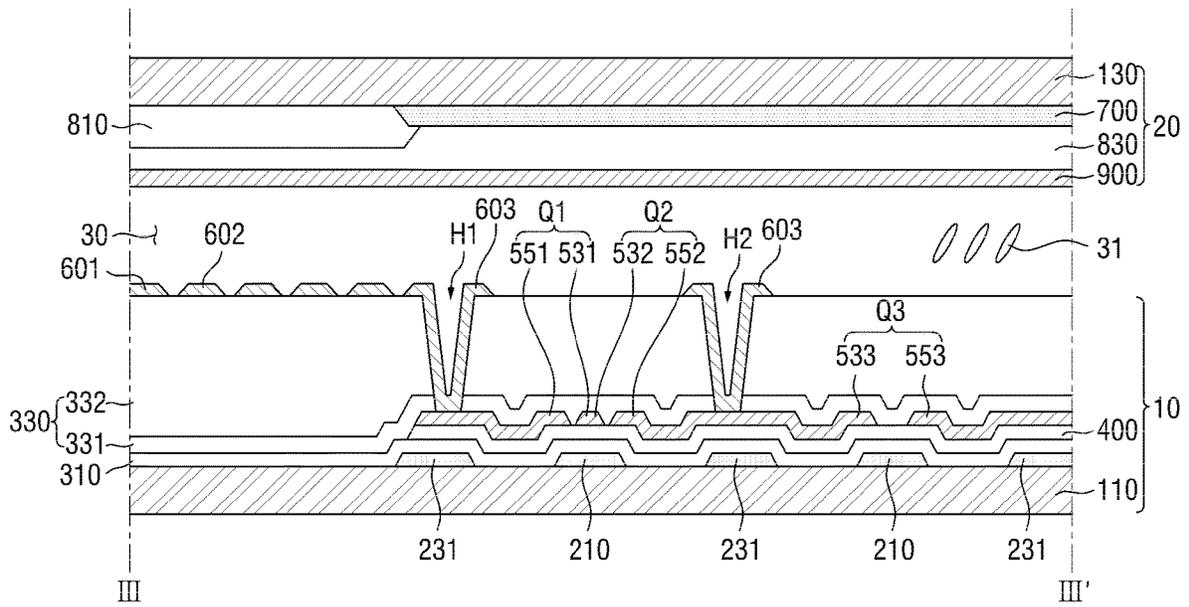


FIG. 4

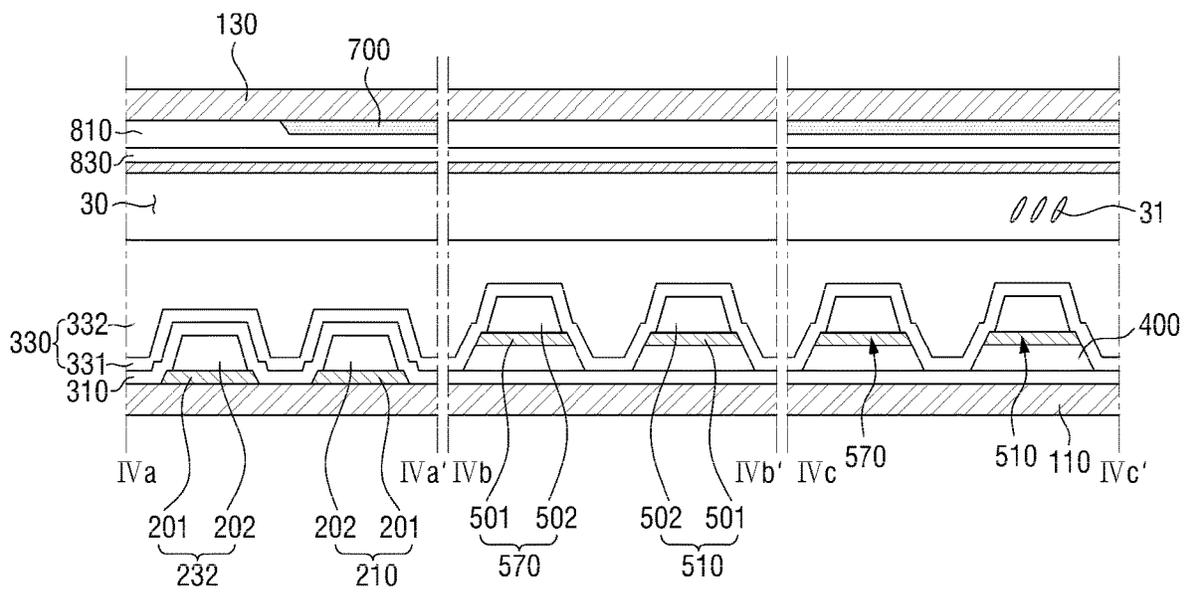


FIG. 5

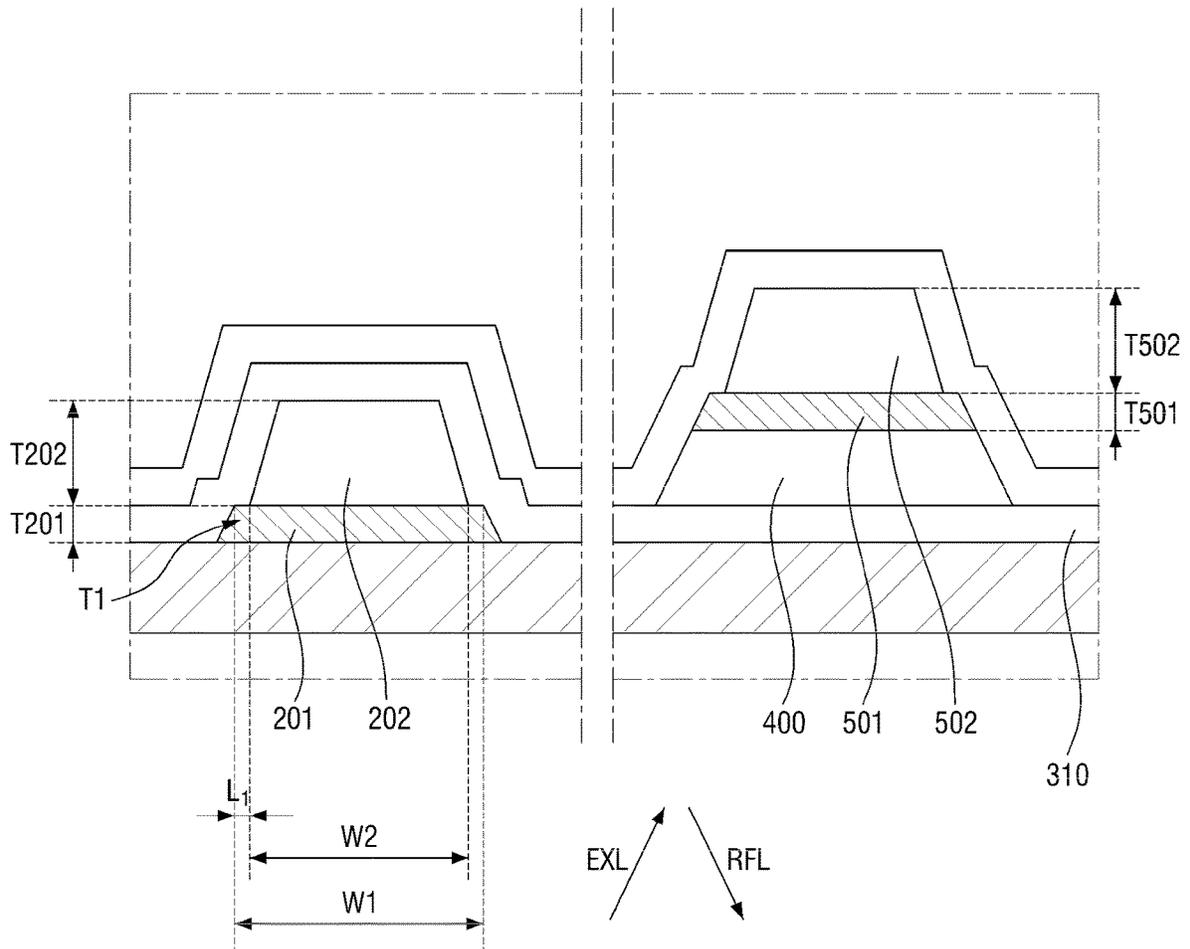


FIG. 6

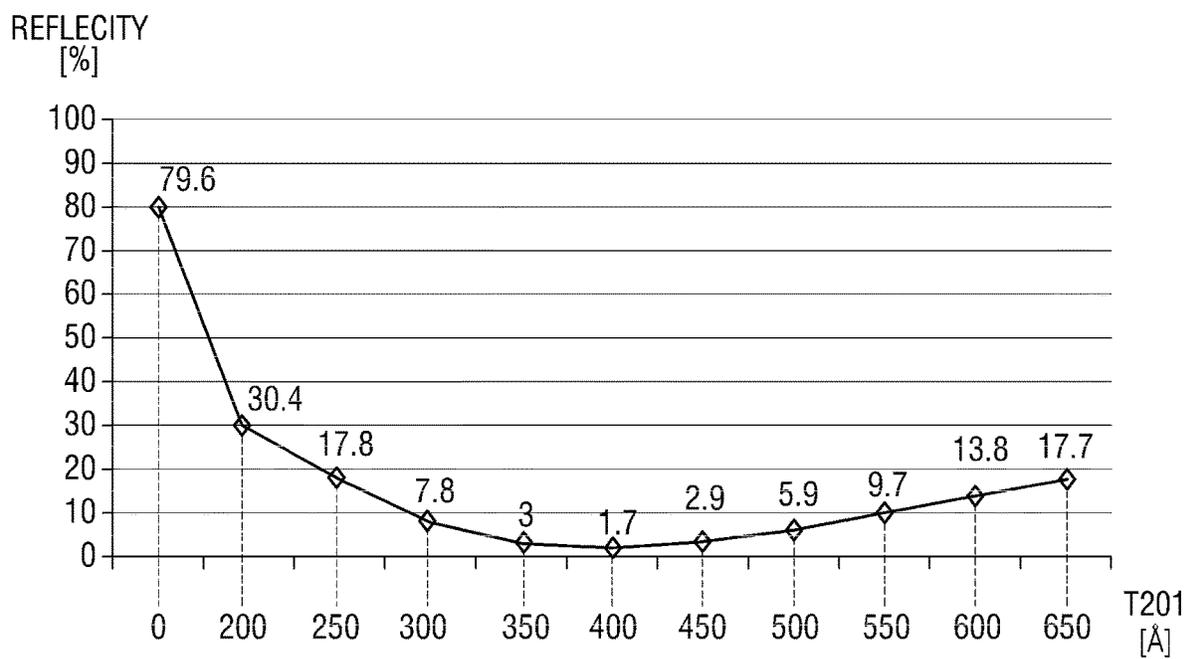


FIG. 7

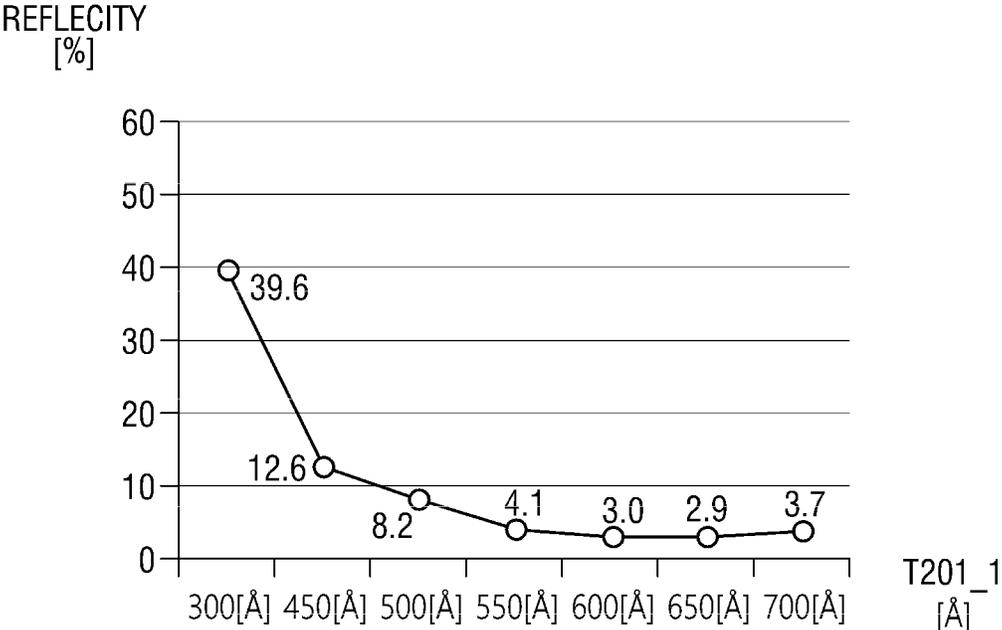




FIG. 9

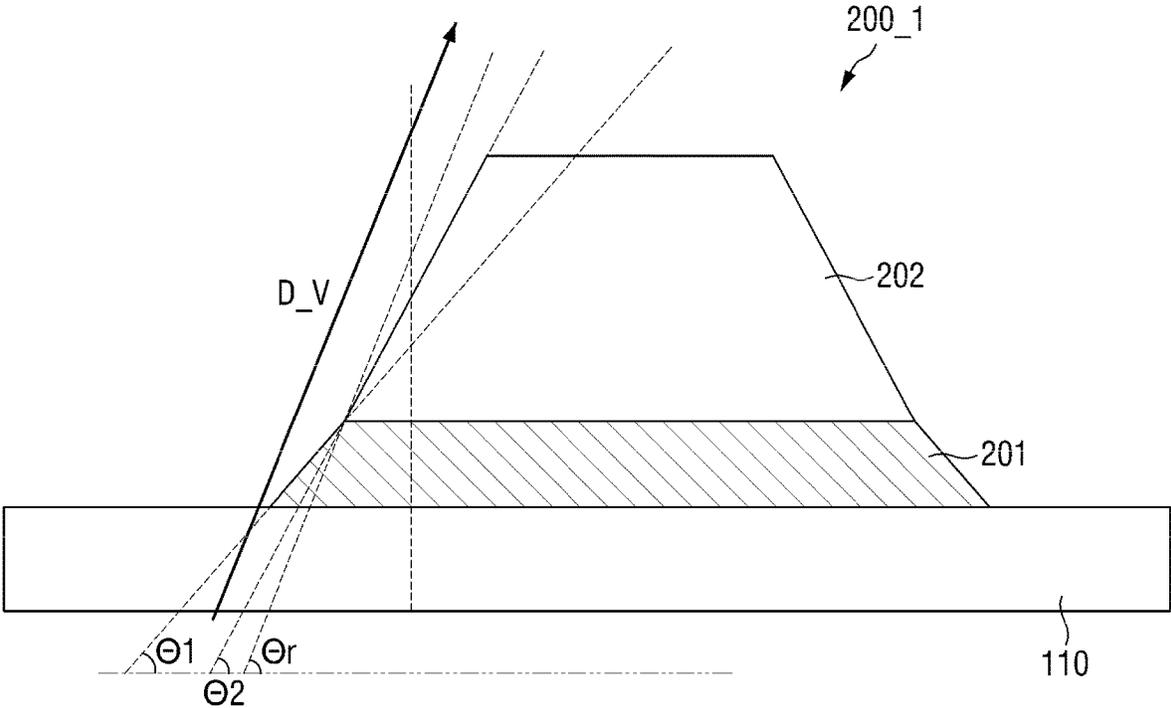


FIG. 10

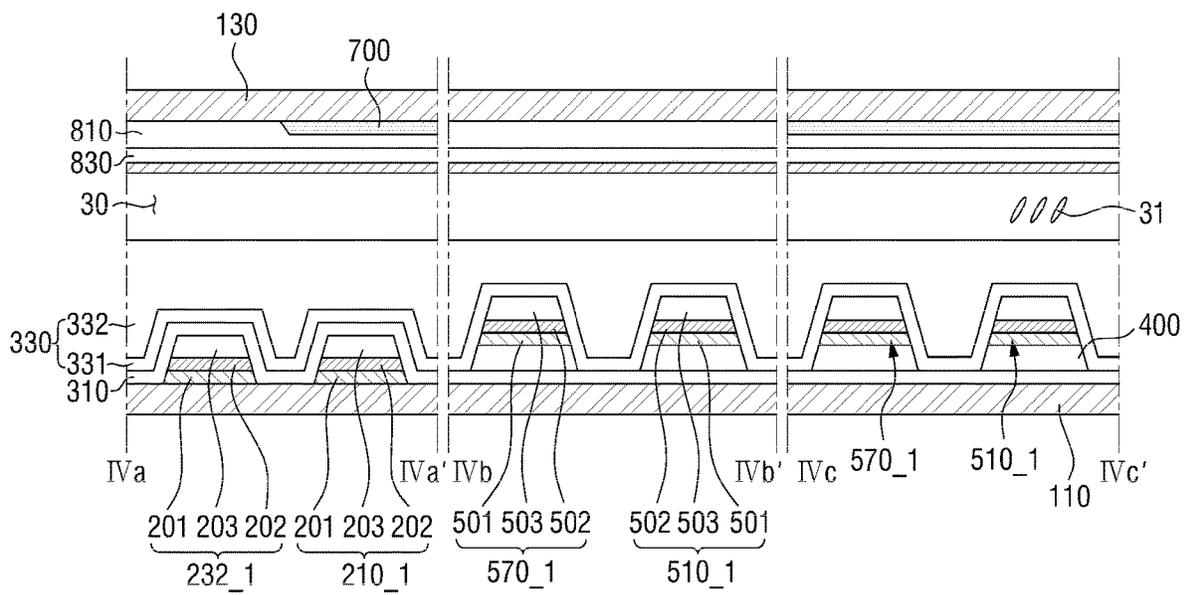


FIG. 11

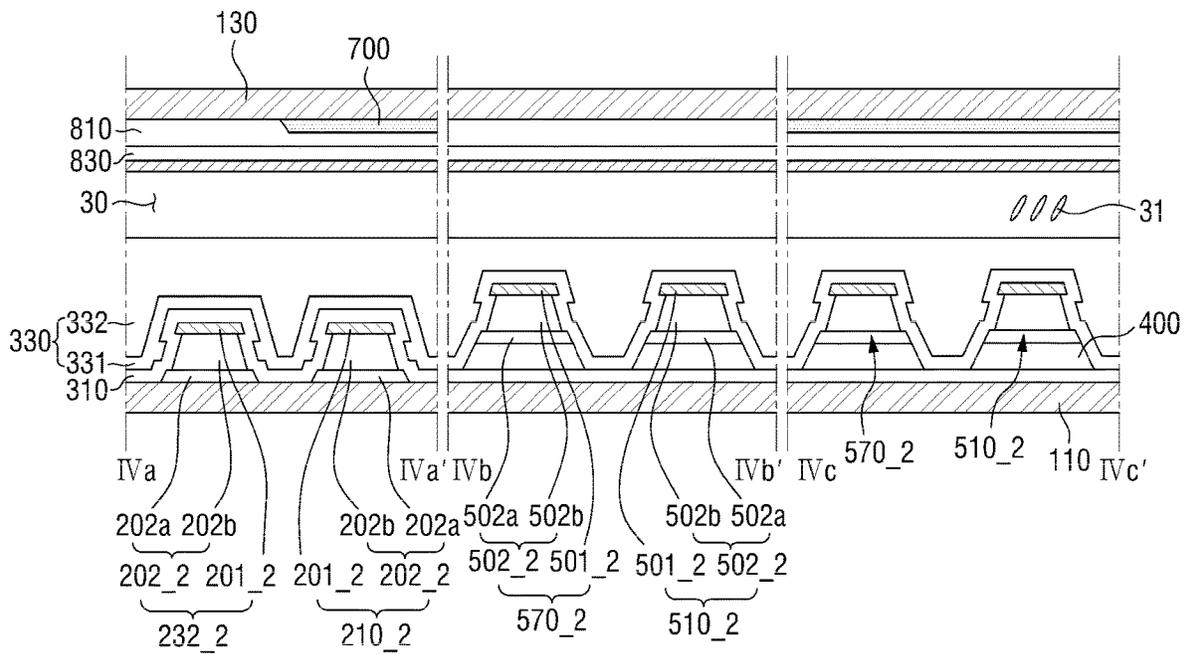
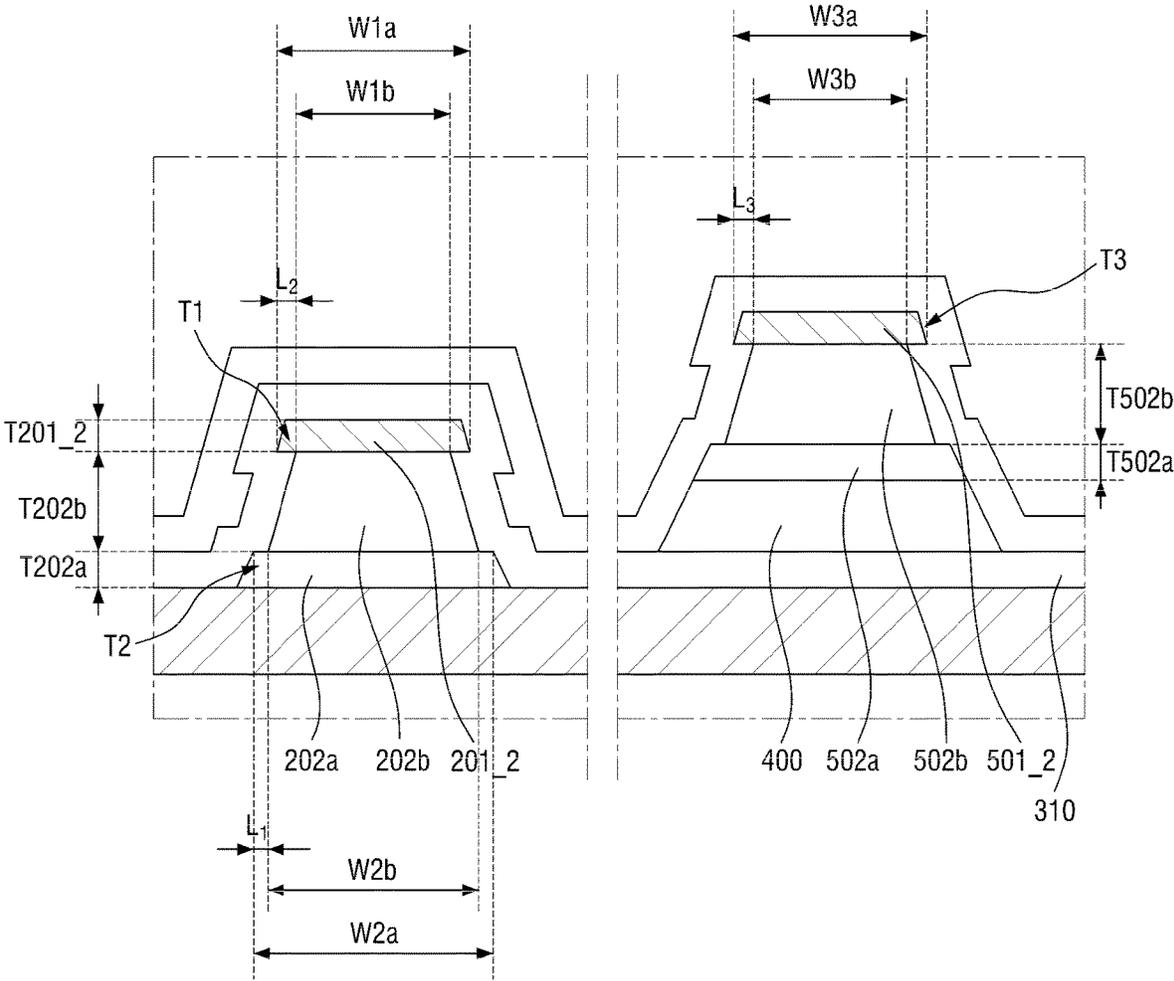


FIG. 12



## WIRING SUBSTRATE AND DISPLAY DEVICE INCLUDING WIRING SUBSTRATE

This application claims priority to Korean Patent Application No. 10-2018-0083049 filed on Jul. 17, 2018 in the Korean Intellectual Property Office; the disclosure of the Korean Patent Application is incorporated herein by reference in its entirety.

### BACKGROUND

#### 1. Field

The technical field relates to a wiring substrate and a display device including the wiring substrate.

#### 2. Description of the Related Art

Modern display devices include liquid crystal display (LCD) devices, organic light emitting diode display (OLED) devices, and the like.

A display device may include a plurality of pixels for displaying different colors. The display device may also include driving signal wirings for transmitting driving signals to various functional electrodes arranged for the pixels.

The driving signal wirings are generally required to have low electric resistance, high thermal stability, and easy processability.

In a display device, wirings may reflect external light. The external light reflected by the wirings may cause significant deterioration of display quality, such as significant deterioration of contrast, of the display device.

### SUMMARY

An embodiment may be related to a display device with a desirable aperture ratio, sufficient resolution, satisfactory display quality, and/or suppressed reflection of external light.

An embodiment may be related to a wiring substrate for a display device having both sufficient resolution and satisfactory display quality.

An embodiment of a display device includes a first base; and a first wiring layer disposed on the first base and including a conductive metal layer and a metal oxide layer mutually laminated; wherein the metal oxide layer includes molybdenum oxide, and the conductive metal layer has a tapered cross-sectional shape, and has a taper angle  $30^\circ$  to  $75^\circ$ .

An embodiment of a wiring substrate includes a first base; and a first wiring layer disposed on the first base and including a conductive metal layer and a metal oxide layer mutually laminated; wherein the metal oxide layer includes molybdenum oxide, and the conductive metal layer has a tapered cross-sectional shape, and has a taper angle  $30^\circ$  to  $75^\circ$ .

An embodiment of a display device includes a first base; and a first wiring layer disposed on the first base and including a conductive metal layer and a metal oxide layer mutually laminated; wherein the metal oxide layer includes  $\text{Mo}_x\text{Ta}_y\text{O}_z$ , and the conductive metal layer has a tapered cross-sectional shape, and a content of tantalum in metal atoms is 0.5 at % to 20 at %.

An embodiment may be related to a display device. The display device may include a first base, a metal oxide layer overlapping a face of the first base, and a conductive metal layer directly contacting the metal oxide layer. The metal

oxide layer may include molybdenum oxide. A side of the metal oxide layer may be oriented at a first angle relative to the face of the first base. A side of the conductive metal layer may be oriented at a second angle relative to the face of the first base. A size of the second angle may be in a range of 30 degrees to 75 degrees.

A light reflectance of the metal oxide layer may be lower than a light reflectance of the conductive metal layer.

A first wiring layer of the display device may include the metal oxide layer and the conductive metal layer. A light reflectance of the first wiring layer to light having a wavelength of 550 nm incident from the face of the first base may be 6.0% or less.

A maximum thickness of the metal oxide layer in a direction perpendicular to the face of the first base may be in a range of 100 Å to 2000 Å.

The metal oxide layer may be disposed directly on the first base and disposed between the conductive metal layer and the first base.

The first angle may be smaller than the second angle.

The size of the second angle may be in a range of 45 degrees to 70 degrees.

The side of the metal oxide layer may be directly connected to the side of the conductive metal layer.

The metal oxide layer may directly contact a face of the conductive metal layer and may protrude beyond the face of the conductive metal layer in a direction parallel to the face of the first base.

The metal oxide layer further may include tantalum. A content of the tantalum in metal atoms may be in a range of 0.5 at % to 12 at % in the metal oxide layer.

The conductive metal layer may include a first metal layer and a second metal layer. The first metal layer may be disposed between the metal oxide layer and the second metal layer. The second metal layer may have higher electrical conductivity than the first metal layer.

The conductive metal layer may include a first metal layer and a second metal layer. The first metal layer may be disposed between the metal oxide layer and the second metal layer. The second metal layer has higher electrical conductivity than the first metal layer.

A first wiring layer of the display device may include the metal oxide layer and the conductive metal layer. A light reflectance of the first wiring layer to light having a wavelength of 550 nm incident from the face of the metal oxide layer may be 6.0% or less.

The conductive metal layer may include a first metal layer and a second metal layer. The second metal layer may be disposed between the first metal layer and the metal oxide layer and has higher electrical conductivity than the first metal layer.

A maximum thickness of the metal oxide layer in a direction perpendicular to the face of the first base may be greater than a maximum thickness of the first metal layer in the direction and may be smaller than a maximum thickness of the second metal layer in the direction.

The maximum thickness of the metal oxide layer in the direction may be in a range of 100 Å to 2000 Å.

The first metal layer may include a refractory metal. The second metal may include at least one of copper and silver.

A first face of the first metal layer and a first face of the second metal layer may be positioned between a second face of the first metal layer and a second face of the second metal layer. The first face of the first metal layer may be wider than the first face of the second metal layer in a direction parallel to the face of the first base.

The metal oxide layer may directly contact a face of the conductive metal layer and may protrude beyond the conductive metal layer in a direction parallel to the face of the first base.

An embodiment may be related to a wiring substrate. The wiring substrate may include a first base, a metal oxide layer overlapping a face of the first base, and a conductive metal layer directly contacting the metal oxide layer. The metal oxide layer may include molybdenum oxide. A side of the conductive metal layer may be oriented at an angle relative to the face of the first base. A size of the angle may be in a range of 30 degrees to 75 degrees.

An embodiment may be related to a display device. The display device may include a first base, a conductive metal layer overlapping a face of the first base, and a metal oxide layer directly contacting the conductive metal layer. The metal oxide layer may include  $\text{Mo}_x\text{Ta}_y\text{O}_z$ . A side of the conductive metal layer may be oriented at an acute angle relative to the face of the first base. A content of tantalum in metal atoms may be in a range of 0.5 at % to 20 at % in the conductive metal layer.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an exploded perspective view of a display device according to an embodiment.

FIG. 2 is a layout view (or plan view) of pixels included in the display device of FIG. 1 according to an embodiment.

FIG. 3 is a cross-sectional view taken along the line III-III' of FIG. 2 according to an embodiment.

FIG. 4 is cross-sectional view taken along the line IVa-IVa', IVb-IVb', and IVc-IVc' of FIG. 2 according to an embodiment.

FIG. 5 is a cross-sectional view showing a first wiring layer and a second wiring layer included in the pixels of FIG. 2 according to an embodiment.

FIG. 6 is a graph showing light reflectance values in a visible light wavelength band with respect to thickness values of a metal oxide layer included in the first wiring layer of FIG. 5 according to an embodiment.

FIG. 7 is a graph showing light reflectance values in a visible light wavelength band with respect to thickness values of a metal oxide layer included in the first wiring layer of FIG. 5 according to an embodiment.

FIG. 8 and FIG. 9 are cross-sectional views showing the first wiring layer of FIG. 5 according to embodiments.

FIG. 10 is a cross-sectional view showing a first wiring layer and a second wiring layer included in the pixels of FIG. 2 according to an embodiment.

FIG. 11 and FIG. 12 are cross-sectional views showing a first wiring layer and a second wiring layer included in the pixel of FIG. 2 according to embodiments.

#### DETAILED DESCRIPTION

Example embodiments are described with reference to the accompanying drawings. Practical embodiments may be embodied in many different forms and should not be construed as being limited to the described embodiments. Like reference numerals may refer to like elements.

The terminology used herein is for the purpose of describing particular embodiments. As used herein, the singular forms "a", "an" and "the" may include the plural forms as well, unless the context clearly indicates otherwise. The terms "comprises" and/or "comprising" may specify the presence of stated features steps, and/or components, but do

not preclude the presence or addition of one or more other features steps, and/or components.

Although the terms "first," "second," etc. may be used herein to describe various elements, these elements, should not be limited by these terms. These terms may be used to distinguish one element from another element. Thus, a first element may be termed a second element without departing from teachings of one or more embodiments. The description of an element as a "first" element may not require or imply the presence of a second element or other elements. The terms "first," "second," etc. may also be used herein to differentiate different categories or sets of elements. For conciseness, the terms "first," "second," etc. may represent "first-type (or first-set)," "second-type (or second-set)," etc., respectively.

When a first element is referred to as being "on", "connected to," or "coupled to" a second element, the first element can be directly on, connected, or coupled to the second element, or one or more intervening elements may be present between the first element and the second element. When a first element is referred to as being "directly on", "directly connected to," or "directly coupled to" a second element, there are no intended intervening elements (except environmental elements such as air) present between the first element and the second element. The term "and/or" may include any and all combinations of one or more of the associated listed items.

The term "connect" may mean "electrically connect"; the term "isolate" may mean "electrically isolate"; the term "insulate" may mean "electrically insulate"; the term "contact" may mean "directly contact" or "direct contact."

FIG. 1 is an exploded perspective view of a display device according to an embodiment.

Referring to FIG. 1, a display device 1 includes a display panel 1a and optionally a light source unit 1b providing light to the display panel 1a.

The display panel 1a includes pixels PXa and PXb, and the pixels PXa and PXb may be arranged in a substantially matrix form along a first direction X and a second direction Y. A pixel may express one or more of predetermined primary colors. One pixel may be a minimum unit capable of expressing one or more colors independent of other pixels. The primary colors may include red, green, and blue. For example, the first pixel PXa and the second pixel PXb arranged along the first direction X may express different primary colors.

The display panel 1a may include driving signal wirings, and the driving signal wirings may include a gate signal wiring 210 extending in the first direction X and a data signal wiring 510 extending in the second direction Y and isolated from the gate signal wiring 210. Each of the gate signal wiring 210 and the data signal wiring 510 is connected to a driving unit (not shown) and to a pixel electrode 600 disposed in a pixel to transmit a driving signal from the driving unit to the pixel.

The light source unit 1b may be disposed at one side of the display panel 1a to provide light having a specific wavelength to the display panel 1a. For example, the light source unit 1b may be disposed at the upper side of the display panel 1a. In this case, the lower surface of the display panel 1a may be a display surface, and an image can be displayed on the display surface. As another example, the light source unit 1b may be disposed at the lower side of the display panel 1a. In this case, the upper surface of the display panel 1a may be a display surface, and an image can be displayed on the display surface.

The light source unit **1b** may include a light source (not shown) directly emitting light and a light guide plate (not shown) guiding the path of light received from the light source and emitting the light toward the display panel **1a**. The light guide plate may have a high light transmittance and may include at least one of a glass material, a quartz material, and a plastic material such as polyethylene terephthalate.

The light source may be a light emitting diode (LED) or an organic light emitting diode (OLED). For example, the light source may emit a blue light or a white light.

Although not shown in the drawings, at least one optical sheet may be disposed between the display panel **1a** and the light source unit **1b**. The optical sheet may include at least one of a prism sheet, a diffusion sheet, a polarizing sheet (or a reflective polarizing sheet), a lenticular lens sheet, and a micro lens sheet. The optical sheet may improve the display quality of the display device **1** by modulating the optical characteristics of light provided from the light source unit **1b** and traveling toward the display panel **1a**. For example, the optical sheet may collect light, diffuse/scatter light, and/or modulate polarizing characteristics.

FIG. 2 is a layout view (or plan view) of pixels included in the display device of FIG. 1 according to an embodiment. FIG. 3 is a cross-sectional view taken along the line III-III' of FIG. 2 according to an embodiment.

Referring to FIGS. 1 to 3, the display panel **1a** may include a lower substrate **10**, an upper substrate **20** overlapping the lower substrate **10**, and a liquid crystal layer **30** disposed between the substrates **10** and **20**. The liquid crystal layer **30** may be encapsulated by the lower substrate **10**, the upper substrate **20**, and an encapsulating member (not shown) that attach these substrates **10** and **20** to each other. The lower substrate **10** may be a wiring substrate provided with driving signal wirings for driving the display panel **1a**, and the upper substrate **20** may be a color conversion substrate provided with a color conversion pattern.

The lower substrate **10** may include a first base **110** (or a first base substrate), a first wiring layer **200** (indicated in FIG. 2), a first insulating layer **310**, an active layer **400**, a second wiring layer **500** (indicated in FIG. 2), a second insulating layer **330**, and a pixel electrode **600** (indicated in FIG. 2).

The first base **110** may be a transparent insulating substrate. For example, the first base **110** may be a substrate made of a glass material, a quartz material, or a translucent plastic material. In an embodiment, the first base **110** may have flexibility, and the display device **1** may be a curved display device.

The first wiring layer **200** may be disposed on the first base **110**. The first wiring layer **200** may be disposed directly on the first base **110**. The first wiring layer **200** may include a gate signal wiring **210** and a sustain electrode **230**. The gate signal wiring **210** and the sustain electrode **230** may be disposed on the same layer. For example, the gate signal wiring **210** and the sustain electrode **230** may have the same structure, may be made of the same material, and may be simultaneously formed through one process (for example, a mask process).

The gate signal wiring **210** may extend along substantially the first direction X. The gate signal wiring **210** may transmit a gate driving signal provided from a gate driving unit (not shown) to a switching element disposed in each of the pixels **PXa** and **PXb**. For example, the pixels arranged along the first direction X may share one gate signal wiring **210**.

A part of the gate signal wiring **210** may form the gate electrode of the switching element. For example, parts of the gate signal wiring **210** may form control terminals (or control electrodes) of a first switching element **Q1**, a second switching element **Q2**, and a third switching element **Q3**. A control terminal of a switching element may protrude from the gate signal wiring **210**.

The sustain electrode **230** may overlap a part of the second wiring layer **500** and/or a part of the pixel electrode **600**. The sustain electrode **230** may form a storage capacitor together with the second wiring layer **500** (and/or the pixel electrode **600**) and a dielectric layer (or an insulating layer) interposed between the sustain electrode **230** and the second wiring layer **500** (and/or the pixel electrode **600**). The storage capacitor may maintain a voltage applied to the pixel electrode **600** during one frame (or a specific time). The sustain electrode **230** may have a partially extended portion. In this case, an overlap area with the second wiring layer **500** and the pixel electrode **600** may be maximized, the capacity of the storage capacitor may be maximized, and a voltage may be stably maintained for one frame.

In an embodiment, the sustain electrode **230** may partially overlap the edge of a first sub-pixel electrode **610**. When the first sub-pixel electrode **610** has a substantially rectangular planar shape, the sustain electrode **230** may have a substantially square band including portions **231** extending in the first direction X and portions **232** extending in the second direction Y. In embodiments, the sustain electrode **230** may have other configurations.

In embodiments, the first wiring layer **200** (for example, the gate signal wiring **210** and the sustaining electrode **230**) may include a conductive metal layer and a metal oxide layer. The first wiring layer **200** may have a laminate structure in which a conductive metal layer and a metal oxide layer are laminated. The first insulating layer **310** may be disposed on the first wiring layer **200** over the entire surface of the first base **110**. The first insulating layer **310** may include an insulating material to insulate components from each other. The first insulating layer **310** may be a gate insulating layer for insulating control terminals (or gate electrodes) of switching elements **Q1**, **Q2**, and **Q3** from a channel layer (that is, an active layer **400**). The first insulating layer **310** may include silicon nitride, silicon oxide, silicon oxynitride, or silicon oxynitride.

The active layer **400** may be disposed on the first insulating layer **310**. The active layer **400** may include a semiconductor material. For example, the active layer **400** may include amorphous silicon or polycrystalline silicon, or may include an oxide semiconductor. A part of the active layer **400** may form a channel of the switching element. For example, parts of the active layer **400** may form channels of a first switching device **Q1**, a second switching device **Q2**, and a third switching device **Q3**, and one or more of the channels may be turned on or turned off according to a voltage applied to the gate signal wiring **210**. At least a part of the active layer **400** may extend in substantially the second direction Y and overlap the data signal wiring **510**.

The second wiring layer **500** may be disposed on the active layer **400**. The second wiring layer **500** may include a data signal wiring **510**, a source electrode layer **530**, and a drain electrode layer **550**, and may further include a reference voltage wiring **570**. The data signal wiring **510**, the source electrode layer **530**, the drain electrode layer **550**, and the reference voltage wiring **570** may be disposed on the same layer. For example, the data signal wiring **510**, the source electrode layer **530**, the drain electrode layer **550**, and the reference voltage wiring **570** may have the same struc-

ture, may be made of the same material, and may be simultaneously formed through one process.

The data signal wiring **510** may extend along substantially the second direction Y. The data signal wiring **51** may transmit a data driving signal provided from a data driving unit (not shown) to a switching element disposed in each of pixels arranged in a same pixel column along the second direction Y.

The source electrode layer **530** may include a first source electrode **531**, a second source electrode **532**, and a third source electrode **533**. The first source electrode **531**, the second source electrode **532**, and the third source electrode **533** may serve as the input terminals of the first switching device **Q1**, the second switching device **Q2**, and the third switching device **Q3**, respectively.

The first source electrode **531** may protrude from the data signal wiring **510** and may be formed integrally with the data signal line **510**. The first source electrode **531** may be spaced from the first drain electrode **551** on the gate signal wiring **210** and the active layer **400**.

Similarly, the second source electrode **532** may protrude from the data signal wiring **510** and may be formed integrally with the data signal wiring **510** and the first source **531**. The second source electrode **532** may be spaced from the second drain electrode **552** on the gate signal wiring **210** and the active layer **400**.

The third source electrode **533** may extend from the second drain electrode **552** and may be formed integrally with the second drain electrode **552**. The third source electrode **533** may be spaced from the third drain electrode **553** on the gate signal wiring **210** and the active layer **400**.

The drain electrode layer **550** may include a first drain electrode **551**, a second drain electrode **552**, and a third drain electrode **553**. The first drain electrode **551**, the second drain electrode **552**, and the third drain electrode **553** may serve as the output terminals of the first switching device **Q1**, the second switching device **Q2**, and the third switching device **Q3**, respectively.

The first drain electrode **551** may be spaced from the first source electrode **531** on the gate signal wiring **210** and the active layer **400**. The first drain electrode **551** may be electrically connected to a first sub-pixel electrode **610** (which includes portions **601**, **602**, and **603**) through a first contact hole **H1**.

Similarly, the second drain electrode **552** may be spaced from the second source electrode **532** on the gate signal wiring **210** and the active layer **400**. The second drain electrode **552** may be electrically connected to the second sub-pixel electrode **630** through a second contact hole **H2**. The second drain electrode **552** may be integrally formed with the third source electrode **533**.

The third drain electrode **553** may be spaced from the third source electrode **533** on the gate signal wiring **210** and the active layer **400**.

The reference voltage wiring **570** may extend in substantially the second direction (Y). For example, a portion of the reference voltage wiring **570**, the portion extending in the second direction Y, may overlap a stem portion **601** of the pixel electrode **600**. When the reference voltage wiring **570** overlap the stem portion **601** of the pixel electrode **600**, the luminance deterioration due to the reference voltage wiring **570** passing through an opening region can be minimized. A reference voltage may be applied to the reference voltage wiring **570**.

In an embodiment, a part of the reference voltage wiring **570** may partially form the third drain electrode **553**. For example, the reference voltage wiring **570** may simultane-

ously serve as an output terminal of the third switching device **Q3**. In an embodiment, the reference voltage wiring **570** and the third drain electrode **553** may be physically separated from each other, but may also be electrically connected to each other.

In embodiments, the second wiring layer **500** (for example, the data signal wiring **510**, the source electrode layer **530**, the drain electrode layer **550**, and the reference voltage wiring **570**) may include a conductive metal layer and a metal oxide layer. The second wiring layer **500** may have a laminate structure in which a conductive metal layer and a metal oxide layer are laminated.

The second insulating layer **330** may be disposed on the second wiring layer **500** over the entire surface of the first base **110**. The second insulating layer **330** may include an insulating material. The second insulating layer **330** may isolate the second wiring layer **500** from the pixel electrode **600**. The second insulating layer **330** may have a laminate structure of a plurality of layers. For example, the second insulating layer **330** may have a double-layer structure including a protective layer **331** made of an inorganic material and a planarization layer **332** made of an organic material.

Contact holes may be formed in the second insulating layer **330**. For example, the first contact hole **H1** may penetrate the second insulating layer **330** to partially expose the first drain electrode **551**, and the second contact hole **H2** may penetrate the second insulating layer **330** to partially expose the second drain electrode **552**.

The pixel electrode **600** may be disposed on the second insulating layer **330**. The pixel electrode **600** may form an electric field in a liquid crystal layer **30** together with a common electrode **900** to control the alignment direction of liquid crystals **31** in the corresponding pixel. The pixel electrodes **600** may be disposed in the respective pixels **PXa** and **PXb**, and voltages may be applied to the pixel electrodes **600** independently of each other. The pixel electrode **600** may be a transparent electrode made of a transparent conductive material. Examples of the material for forming the transparent electrode may include indium tin oxide (ITO) and indium zinc oxide (IZO).

In an embodiment, in one pixel, the pixel electrode **600** may include a first sub-pixel electrode **610** and a second sub-pixel electrode **630** spaced from each other. The planar area occupied by the first sub-pixel electrode **610** may be smaller than the planar area occupied by the second sub-pixel electrode **630**.

Each of the first sub-pixel electrode **610** and the second sub-pixel electrode **630** may have a substantially rectangular shape in a plan view, and may be a pattern electrode having domain dividing means. For example, each of the first sub-pixel electrode **610** and the second sub-pixel electrode **630** may include a stem portion **601**, a plurality of branch portions **602**, and a connection portion **603** extending from the branch portions **602**.

The stem portion **601** may be formed in a substantially cross shape. The stem portion **601** may overlap the reference voltage wiring **570** extending in substantially the second direction Y. The branch portions **602** may extend in a direction inclined from the cross-shaped stem portion **601**, for example, in a direction of about 45° with respect to the extending direction of the stem portion **601**. That is, each of the first sub-pixel electrode **610** and the second sub-pixel electrode **630** may have four domains divided by the stem portion **601** and having different alignment directions of the branch portions **602**. In this case, the liquid crystal control ability of the display device **1** may be improved, the viewing

angle of the display device **1** may be improved, and the luminance and response speed of the display device **1** may be improved.

The connection portion **603** of the first sub-pixel electrode **610** may electrically connect the first sub-pixel electrode **610** and the first drain electrode **551** through the first contact hole **H1**, and the connection portion **603** of the second sub-pixel electrode **630** may electrically connect the second sub-pixel electrode **630** and the second drain electrode **552** through the second contact hole **H2**.

The first switching element **Q1**, the second switching element **Q2**, and the third switching element **Q3** share one gate signal wiring **210** and may be controlled at the same time. A data voltage provided from the data signal wiring **510** may be applied to the first sub-pixel electrode **610** through the first switching element **Q1**. Since the second drain electrode **552** of the second switching element **Q2** is electrically connected to the reference voltage wiring **570** through the third switching element **Q3**, a predetermined voltage having a value between the data voltage provided from the data signal wiring **510** and the reference voltage provided from the reference voltage wiring **570** may be applied to the second sub-pixel electrode **630**. Therefore, a voltage having a relatively lower magnitude than that applied to the first sub-pixel electrode **610** may be applied to the second sub-pixel electrode **630**. The first sub-pixel electrode **610** and the second sub-pixel electrode **630** to which different voltages are applied are disposed in one pixel to improve the side visibility of the display device **1**.

In FIG. 2, the edge of the first sub-pixel electrode **610** overlaps the sustain electrode **230**. In an embodiment, the edge of the second sub-pixel electrode **630** may overlap the sustain electrode **230**. In an embodiment, both the first sub-pixel electrode **610** and the second sub-pixel electrode **630** may overlap the sustain electrode **230**.

The upper substrate **20** may include a second base **130**, a light blocking member **700** disposed on one surface (lower surface in the drawing) of the second base **130**, a color conversion pattern **810** disposed on the second base **130**, an overcoat layer **830** disposed on the color conversion pattern **810** and the light blocking member **700**, and a common electrode **900** disposed on the overcoat layer **830**.

The second base **130** may be a transparent substrate. The first base **110** and the second base **130** may be made of the same material or different materials.

The light blocking member **700** may be disposed on the second base **130**. The light blocking member **700** may be made of a material capable of blocking light in a visible light wavelength band. The light blocking member **700** may overlap the first switching element **Q1**, the second switching element **Q2**, and the third switching element **Q3**, thereby preventing light leakage in an unintended area.

The light blocking member **700** may have a line shape extending in the first direction **X** and may overlap the switching elements **Q1** to **Q3**. Further, the light blocking member **700** may partially overlap the sustain electrode **230**, a part of the active layer **400**, and a part of the data signal wiring **510**. The gate signal wiring **210** may be completely covered by the light blocking member **700**. In FIG. 3, the light blocking member **700** is included in the upper substrate **20**. In an embodiment, the light blocking member **700** may be included in the lower substrate **10**. In an embodiment, the light blocking member **700** may be unnecessary.

The color conversion pattern **810** may partially overlap the light shielding member **700** and may overlap the pixel electrode **600**. A color conversion pattern **810** may be disposed at a position corresponding to each of the pixels

**PXa** and **PXb**. The light having passed through the color conversion pattern **810** may be in a specific wavelength band. Therefore, the pixels **PXa** and **PXb** of the display device **1** may express different colors.

The color conversion pattern **810** may be a color filter including a colorant such as a dye or a pigment. The colorant may selectively absorb a specific wavelength band of incident light. The color conversion pattern **810** may absorb light of a specific wavelength band in incident light and selectively transmit light of another specific wavelength band in incident light.

The color conversion pattern **810** may be a wavelength shift member including a wavelength shift material such as a quantum dot material or a fluorescent material. The wavelength shift material may convert or shift a peak wavelength of incident light to another specific peak wavelength. The color conversion pattern **810** may emit light having a specific peak wavelength after absorbing at least a part of incident light.

The overcoat layer **830** may be disposed on the color conversion pattern **810** over the entire surface of the second base **130**. The overcoat layer **830** may planarize a plurality of components laminated on the second base **130** to provide a surface on which the common electrode **900** is to be disposed.

The common electrode **900** may be disposed on the overcoat layer **830**. The common electrode **900** may be integrally formed for all the pixels **PXa** and **PXb**, and a common voltage may be applied to the common electrode **900**. The common electrode **900** may be a transparent electrode.

The liquid crystal layer **30** may include initially aligned liquid crystals **31**. For example, the liquid crystals **31** may have a negative dielectric anisotropy and may be vertically aligned in an initial alignment state. The liquid crystals **31** may have a predetermined pretilt angle in the initial alignment state. When an electric field is formed between the pixel electrode **600** and the common electrode **900**, the liquid crystals **31** may change the amount of light transmitted through the liquid crystal layer **30**. As another example, the liquid crystals **31** may have a positive dielectric anisotropy and may be horizontally aligned in the initial alignment state. When an electric field is formed, the liquid crystals **31** may change the transmission of light.

FIG. 4 is cross-sectional view taken along the line IVa-IVa', IVb-IVb', and IVc-IVc' of FIG. 2 according to an embodiment. FIG. 5 is a cross-sectional view showing a first wiring layer and a second wiring layer included in the pixel of FIG. 2 according to an embodiment. FIG. 6 is a graph showing light reflectance values in a visible light wavelength band with respect to thickness values of a metal oxide layer included in the first wiring layer of FIG. 5 according to an embodiment.

In FIG. 4, the cross-section taken along the line IVa-IVa' represents the sustain electrode **230** and the gate signal line **210**, the cross-section taken along the line IVb-IVb' represents the reference voltage wiring **570** and the data signal wiring **510** in an area not overlapping the light blocking member **700**, and the cross-section taken along the line IVc-IVc' represents the reference voltage wiring **570** and the data signal wiring **510** in an area overlapping the light blocking member **700**.

Referring to FIGS. 1 to 6, the first wiring layer **200** may have a laminate structure in which a first metal oxide layer **201** and a first conductive metal layer **202** are laminated, and the second wiring layer **500** may have a laminate structure in which a second metal oxide layer **501** and a second

conductive metal layer **502** are laminated. In FIGS. **4** and **5**, the first wiring layer **200** includes the first metal oxide layer **201** and the first conductive metal layer **202**, and the second wiring layer **500** includes the second metal oxide layer **501** and the second conductive metal layer **502**. In embodiments, the second wiring layer **500** may not include the second metal oxide layer **501**, or the first wiring layer **200** may not include the second metal oxide layer **201**.

The first wiring layer **200** may include a first metal oxide layer **201** and a first conductive metal layer **202**.

The first metal oxide layer **201** may be disposed on the first base **110**. The first metal oxide layer **201** may be a single layer. The first metal oxide layer **201** may include a material having a higher light absorbance and a smaller light reflectance than the first conductive metal layer **202**.

In embodiments, the first metal oxide layer **201** may include molybdenum oxide (MoOx). For example, the first metal oxide layer **201** may include molybdenum dioxide (MoO<sub>2</sub>). As another example, the first metal oxide layer **201** may include molybdenum dioxide (MoO<sub>2</sub>) and molybdenum trioxide (MoO<sub>3</sub>).

The refractive index of molybdenum oxide may be about 2.55, and the absorption coefficient (or extinction coefficient, k) of molybdenum oxide may be 3697.6 cm<sup>-1</sup>. In this case, the refractive index of the first metal oxide layer **201** including molybdenum oxide may be in a range of 2.2 to 2.6, and the absorption coefficient of the first metal oxide layer **201** may increase in proportion to the increase in thickness and may be 0.40 to 0.90.

The first conductive metal layer **202** may be disposed on the first metal oxide layer **201**. The first conductive metal layer **202** may be disposed directly on the first metal oxide layer **201**. The first conductive metal layer **202** may include a metal material having low specific resistance and excellent electrical conductivity. For example, the first conductive metal layer **202** may include copper (Cu), silver (Ag), aluminum (Al), or an alloy. The first conductive metal layer **202** may exhibit opaque properties. For example, the first conductive metal layer **202** may be a copper layer including only copper, or may be a single layer including an alloy of copper.

In an embodiment, the refractive index of the first metal oxide layer **201** may be greater than that of the first conductive metal layer **202**. For example, the refractive index of the first metal oxide layer **201** to light in the visible light wavelength band may be in a range of 2.2 to 2.6, and the refractive index of the first metal oxide layer **201** to light having a wavelength of 550 nm may be in a range of 2.2 to 2.3.

In an embodiment, the thickness T201 of the first metal oxide layer **201** may be smaller than the thickness T202 of the first conductive metal layer **202**. The first metal oxide layer **201** may have a thickness capable of exhibiting a destructive interference with light in the visible light wavelength band (for example,  $T202 = \lambda/4/n$ , where  $\lambda$  is a wavelength of light and n is a refractive index of the first metal oxide layer **201**).

FIG. **6** shows a relationship between the light reflectance of the first metal oxide layer **201** (or the first wiring layer **200** including the first metal oxide layer **201**) to light in the visible light wavelength band (for example, a wavelength of 550 nm) and the thickness T201 of the first metal oxide layer **201** in the third direction Z. It is assumed that the first conductive metal layer **202** includes copper (Cu) and the thickness T202 of the first conductive metal layer **202** is 6000 Å.

When the thickness T201 of the first metal oxide layer **201** is 0 Å (that is, when the first wiring layer **200** includes only the first conductive metal layer **202**), the light reflectance of the first wiring layer **200** may be 79.6%. That is, most of the light EXL incident from the back surface of the first metal oxide layer **201** is reflected, and may be viewed by the user as reflected light RFL.

As the thickness T201 of the first metal oxide layer **201** increases, the light reflectance of the first metal oxide layer **201** gradually decreases. When the thickness T201 of the first metal oxide layer **201** is 400 Å, the light reflectance of the first metal oxide layer **201** may have a minimum value of 1.7%. As the thickness T201 of the first metal oxide layer **201** increases over 400 Å, the light reflectance of the first metal oxide layer **201** gradually increases. When the thickness T201 of the first metal oxide layer **201** is 650 Å, the light reflectance of the first metal oxide layer **201** may be 17.7%.

Since the light reflectance of the first metal oxide layer **201** is determined by the light absorbance, transmittance, and refractive index of the first metal oxide layer **201** and the destructive interference of transmitted light, at a thickness T201 of 400 Å causing destructive interference, the light reflectance of the first metal oxide layer **201** may have a minimum value. As the thickness T201 increases over 400 Å, the light reflectance of the first metal oxide layer **201** slightly increases, but the light absorbance of the first metal oxide layer **201** increases with the increase of the thickness T201, so that the light reflectance of the first metal oxide layer **201** may be reduced again and saturated.

According to embodiments, the thickness T201 of the first metal oxide layer **201** may be in a range of 100 Å to 2,000 Å where light reflectance is reduced to 50% or less, may be in a range of 300 Å to 550 Å where light reflectance is reduced to 10% or less, and may be about 400 Å where light reflectance is minimized. When the visible light wavelength band is in a range of 380 nm to 780 nm, considering the overall light absorbance and destructive interference, the thickness T201 of the first metal oxide layer **201** may be about 500 Å.

When the thickness T201 of the first metal oxide layer **201** is about 500 Å, the light absorbance of the first metal oxide layer **201** (or the first wiring layer **200** including the first metal oxide layer **201**) may be about 40% or more, about 45% or more, about 50% or more, about 55% or more, or about 60% or more. The light reflectance of the first metal oxide layer **201** (or the first wiring layer **200** including the first metal oxide layer **201**) itself may be in a range of 25% to 40%, and the light transmittance thereof may be in a range of 15% to 25%.

The side wall of the first metal oxide layer **201** may protrude beyond the side wall of the first conductive metal layer **202** in the second direction Y and/or the first direction X to form a tip T1. The tip T1 of the first metal oxide layer **201** may improve the stability of the first conductive metal layer **202**. The width W1 of the surface of the first metal oxide layer **201** facing/contacting the first conductive metal layer **202** (that is, the upper surface of the first metal oxide layer **201** in FIG. **5**) may be greater than the width W2 of the surface of the first conductive metal layer **202** facing/contacting the first metal oxide layer **201** (that is, the lower surface of the first conductive metal layer **202** in FIG. **5**). The length L1 of the upper side of the tip of the first metal oxide layer **201** may be about 0.5 μm or less. When the length L1 of the tip is greater than 0.5 μm, the leakage current (off current) of a switching element may remarkably, undesirably increase.

The first metal oxide layer **201** may be located at the lowermost layer of the first wiring layer **200**. The first metal oxide layer **201** having its own high light absorbance and having a destructive interference thickness is disposed at the lowermost position of the first wiring layer **200**, so that the reflectance of the first wiring layer **200** to the light EXL incident from the back surface may be effectively reduced, or the reflected light RFL may be effectively reduced. The reflectance of the first wiring layer **200** to the light EXL having a wavelength of 550 nm incident from the side of the first metal oxide layer **202** (or lower side in the drawing) toward the first wiring layer **200** may be about 6.0% or less, about 3.0% or less, or about 1.7% or less. Since the first wiring layer **200** includes the first conductive metal layer **202**, it may provide excellent electrical conductivity and may function as a wiring and an electrode.

The first wiring layer **200** may include the gate signal wiring **210** and the sustain electrode **230**.

The gate signal wiring **210** extending in the first direction X may completely overlap the line-shaped light blocking member **700** extending in the first direction X. The gate signal wiring **210** may be completely covered and shrouded by the light blocking member **700**.

The sustain electrode **230** may partially overlap the light blocking member **700**. When the sustain electrode **230** includes a portion extending in the first direction X and a portion extending in the second direction Y, at least a part of the portion of the sustain electrode **230** extending in the second direction Y may be exposed to external light without overlapping the light blocking member **700**.

The first wiring layer **200** may have a very low reflectance with respect to light in the visible light wavelength band, and thus the planar area occupied by the light blocking member **700** may be minimized. Even when the light blocking member **700** does not have a portion extending only in the first direction X and not extending in the second direction Y, the display device **1** may have an excellent contrast characteristic. The light blocking member **700** extending in the second direction Y may be absent at the boundary of the adjacent pixels PXa and PXb in the first direction X, so that the aperture ratio of the display device **1** may be improved.

The second wiring layer **500** may include a second metal oxide layer **501** and a second conductive metal layer **502** disposed on the first wiring layer **200** and insulated from the first wiring layer **200**.

The second metal oxide layer **501** is substantially the same as or similar to the above-described first metal oxide layer **201**, and the second conductive metal layer **502** is substantially the same as or similar to the above-described first conductive metal layer **202**.

The first insulating layer **310** may be disposed between the first wiring layer **200** and the second wiring layer **500**. The first insulating layer **310** may isolate the second wiring layer **500** from the first wiring layer **200**.

The active layer **400** may be disposed between the second wiring layer **500** and the first insulating layer **310**. When the second conductive metal layer **501** and the active layer **400** are in contact with each other, the second metal oxide layer **501** may serve as a barrier for preventing ions in the second conductive metal layer **501** from diffusing into the active layer **400**. In some embodiments, when the active layer **400** includes amorphous silicon, an ohmic contact layer (not shown) may be further disposed between the second wiring layer **500** and the active layer **400**. The ohmic contact layer may include n+ hydrogenated amorphous silicon doped with a high concentration of n-type impurities, or may include a

silicide. The ohmic contact layer may reduce a contact resistance between the second wiring layer **500** and the active layer **400**.

The second wiring layer **500** may include the data signal wiring **510** and may further include the reference voltage wiring **570**.

Each of the data signal wiring **510** and the reference voltage wiring **570**, extending in the second direction Y, may partially overlap the light blocking member **700**. At least a part of the data signal wiring **510** and the reference voltage wiring **570** may be exposed to external light without overlapping the light blocking member **700**.

Similarly to the first wiring layer **200**, the second wiring layer **500** may have a very low reflectance with respect to light in the visible light wavelength band, and thus the planar area occupied by the light blocking member **700** may be minimized. Even when the light blocking member **700** does not have a portion extending only in the first direction X and not extending in the second direction Y, the display device **1** may have an excellent contrast characteristic. The light blocking member **700** extending in the second direction Y may be absent at the boundary of the adjacent pixels PXa and PXb in the first direction X, so that the aperture ratio of the display device **1** may be improved.

FIG. 7 is a graph showing light reflectance values in a visible light wavelength band with respect to thickness values of a metal oxide layer included in the first wiring layer of FIG. 5 according to an embodiment.

Referring to FIGS. 1 to 5, the first metal oxide layer **201** (and/or the second metal oxide layer **501**) may further include tantalum. The first metal oxide layer **201** may include  $\text{Mo}_x\text{Ta}_y\text{O}_z$ .

The content of tantalum in the metal atoms in the first metal oxide layer **201** may be about 20.0 at % (atomic percent) or less, about 12 at % or less, or about 2 at % or less. The uppermost of the ratio  $(y/(x+y))$  of y to  $(x+y)$  may be about 0.20. When the content of tantalum is greater than 20 at %, etching stability deteriorates, and thus it is difficult to control an etching surface.

The lowermost limit of the content of tantalum in the metal atoms in the first metal oxide layer **201** is not particularly limited, but, from the viewpoint of processability, the lowermost limit thereof may be about 0.3 at % or more, or about 0.5 at % or more. When the content of tantalum is less than 0.3 at %, the first metal oxide layer **201** may exhibit undesirable etching characteristics and thus be unstable.

As the content of tantalum increases, the light reflectance of the first metal oxide layer **201** to the visible light wavelength band may increase.

FIG. 7 shows a relationship between the light reflectance of the first metal oxide layer **201** (that is, the first metal oxide layer **201** including tantalum) to the light in the visible light wavelength band (for example, a wavelength of 550 nm) and the thickness T201\_1 of the first metal oxide layer **201** in the third direction Z. It is assumed that the first conductive metal layer **202** includes copper (Cu), the thickness T202 of the first conductive metal layer **202** is 6000 Å, and the content of tantalum is about 2.0 at %.

When the thickness T201\_1 of the first metal oxide layer **201** is 300 Å, the light reflectance of the first metal oxide layer **201** may be 39.6%, which may be higher than the light reflectance (30.4% shown in FIG. 6) of the first metal oxide layer **201** including no tantalum.

As the thickness T201\_1 of the first metal oxide layer **201** increases, the light reflectance of the first metal oxide layer **201** gradually decreases. In this case, when the thickness

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T201\_1 of the first metal oxide layer 201 is 650 Å, the light reflectance of the first metal oxide layer 201 may have a minimum value of 2.9%. As the thickness T201 of the first metal oxide layer 201 increases over 650 Å, the light reflectance of the first metal oxide layer 201 may be gradually increased and then saturated.

According to embodiments, the thickness T201\_1 of the first metal oxide layer 201 (including tantalum) may be in a range of 300 Å to 2,000 Å where light reflectance is reduced to 50% or less, may be in a range of 500 Å to 700 Å where light reflectance is reduced to 10% or less, or may be about 600 Å to 650 Å where light reflectance is reduced to 3% or less. Considering the visible light wavelength band about 380 nm to about 780 nm, light absorbance, and destructive interference, or the like, the thickness T201\_1 of the first metal oxide layer 201 may be about 600 Å.

When the first metal oxide layer 201 includes tantalum, the tip T1 may be more easily formed on the side wall of the first metal oxide layer 201. The tip T1 of the first metal oxide layer 201 may protrude beyond the side wall of the first conductive metal layer 202 in the second direction Y and/or the first direction X, and may prevent the light reflected by the first conductive metal layer 202 (that is, the light having reached the conductive metal layer 202 and transmitting the first base 110 without passing through the first metal oxide layer 201) from being viewed by the user.

FIGS. 8 and 9 are cross-sectional views showing the first wiring layer of FIG. 5 according to embodiments.

Referring to FIGS. 5 and 8, a first metal oxide layer 201 may have a tapered cross-sectional shape. Both side walls of the first metal oxide layer 201 may be inclined relative to the bottom face of the first base 110, and the distance between the two opposite side walls (or the width of the first metal oxide layer 201 in the horizontal direction) may decrease as a distance from the first base 110 increases. The first conductive metal layer 202 may also have a tapered cross-sectional shape.

The sidewall of the first metal oxide layer 201 may form a first angle  $\Theta 1$  (or a first taper angle or a first tilt angle) together with the first base 110, and the sidewall of the first conductive layer 202 may form a second angle  $\Theta 2$  (or a second taper angle, a second tilt angle, or a second average angle) together with the first base 110. The first angle  $\Theta 1$  and the second angle  $\Theta 2$  may be acute angles. Each of the first angle  $\Theta 1$  and the second angle  $\Theta 2$  may be an angle defined by a line or surface connecting two ends of the side wall when the corresponding side wall is not planar.

The first angle  $\Theta 1$  of the sidewall of the first metal oxide layer 201 and the second angle  $\Theta 2$  of the sidewall of the second conductive metal layer 202 may be less than or equal to the reference angle  $\Theta r$ . The reference angle  $\Theta r$  is calculated based on the recommended viewing distance (or the minimum viewable distance) of the display device 1, and may be, for example, in a range of 60° to 80°.

For example, when the display device 1 has a rectangular 65-inch display screen, the display device 1 (or the display screen) may have a length of about 1.5 μm and a height of about 0.8 μm depending on an aspect ratio. In this case, the recommended viewing distance for the display device 1 may be about 3.3 μm or more, which is four to eight times the height of the display device 1. When the user is positioned at about 3.3 μm from the display device 1 on a line perpendicular to the display screen and passing through the center point of the display screen, the viewing angle of the user may be about 24.6°. That is, the angle formed by the sight line axis D\_V (or sight line direction) of the central

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user located at the center of the display device 1 with the display device 1 is at least about 77.7° (that is,  $90^\circ - 24.6^\circ / 2 = 77.7^\circ$ ).

According to embodiments, the first angle  $\Theta 1$  of the sidewall of the first metal oxide layer 201 is smaller than 77.7° (that is, the reference angle  $\Theta r$ ), and the second angle  $\Theta 2$  of the sidewall of the second conductive metal layer 202 is smaller than 77.7° (that is, the reference angle  $\Theta r$ ), such that the second conductive metal layer 202 may not be exposed to the central user, and such that the light reflected by the second conductive metal layer 202 may not be viewed by the user.

When the first angle  $\Theta 1$  of the sidewall of the first metal oxide layer 201 is smaller than the second angle  $\Theta 2$  of the sidewall of the second conductive metal layer 202, as shown in FIG. 8, the sidewall of the second conductive metal layer 202 may be spaced from the sight line axis D\_V, and the conductive metal layer 202 may not be exposed to the central user.

In embodiments, even when the first angle  $\Theta 1$  of the sidewall of the first metal oxide layer 201 is greater than 77.7° (that is, the reference angle  $\Theta r$ ), the conductive metal layer 202 may not be exposed to the central user when the first angle  $\Theta 1$  of the sidewall of the first metal oxide layer 201 is smaller than the second angle  $\Theta 2$  of the sidewall of the conductive metal layer 202.

Since the recommended viewing distance is proportional to the height (or length) of the display device 1, even if the size of the display screen of the display device 1 becomes small, The angle formed by the sight line axis D\_V of the central user with the display device 1 may be about 77.7°.

In embodiments, when the user is positioned at about 3.3 μm from the display device 1 on a line perpendicular to the display screen and passing through the boundary of the display screen, the viewing angle of the user may be about 23.7°. That is, the angle formed by the sight line axis D\_V (or sight line direction) of the peripheral user located at one side from the center of the display device 1 with the display device 1 is at least about 66.3° (that is,  $90^\circ - 23.7^\circ = 66.3^\circ$ ).

According to embodiments, when the first angle  $\Theta 1$  of the sidewall of the first metal oxide layer 201 is smaller than 66.3° and the second angle  $\Theta 2$  of the sidewall of the conductive metal layer 202 is smaller than 66.3°, the conductive metal layer 202 may not be exposed to the central user.

As the second angle  $\Theta 2$  of the sidewall of the conductive metal layer 202 decreases, the width W2 of the conductive metal layer 202 is required to increase, or the thickness T202 of the conductive metal layer 202 is required to decrease. Considering the case where the width W2 of the conductive metal layer 202 is at least about 3 μm and the thickness thereof is at least about 0.6 μm, the second angle  $\Theta 2$  of the sidewall of the conductive metal layer 202 may be 45° or more.

The angle (or reference angle  $\Theta r$ ) formed by the sight line axis D\_V of the user with the display screen may be about 77.7° or less depending on the position of the user with respect to the display device 1 (or the display screen of the display device 1). Accordingly, the second angle  $\Theta 2$  of the sidewall of the conductive metal layer 202 may be about 75° or less, or may be about 66.3° or less, about 60° or less, or about 50° or less, and about 30° or more, considering the peripheral user as well as the central user.

Further, when the first angle  $\Theta 1$  of the sidewall of the first metal oxide layer 201 is smaller than the reference angle  $\Theta r$ , the first angle  $\Theta 1$  of the sidewall of the first metal oxide layer 201 may be smaller than the second angle  $\Theta 2$  of the sidewall of the conductive metal layer 202.

In embodiments, the first angle  $\Theta 1$  of the sidewall of the first metal oxide layer **201** may be greater than the reference angle  $\Theta r$ .

Referring to FIGS. **5**, **8**, and **9**, a first metal oxide layer **201** is different from the first metal oxide layer **201** described with reference to FIG. **8** in that it further includes a tip **T1** protruding beyond the side wall of the first conductive metal layer **202**. Since the first metal oxide layer **201** is substantially the same as the first metal oxide layer **201** described with reference to FIG. **8** except for the tip **T1**.

The length **L1** of the tip **T1** may be 0.5  $\mu\text{m}$  or less. Since the thickness **T201** of the first metal oxide layer **201** is at a level of several hundred angstroms, such as 400  $\text{\AA}$  and 600  $\text{\AA}$ , the protruding length **La1** of the first metal oxide layer **201** at the first angle  $\Theta 1$  is much smaller than the length **L1** of the tip **T1**, so that the protruding length **La1** may not be considered in the calculation of the second angle  $\Theta 2$ .

Since the thickness **T202** of the first conductive metal layer **202** is several thousand  $\text{\AA}$  to 20000  $\text{\AA}$ , the distance difference **Ld** (or **L1+La2**) between the lower surface of the first metal oxide layer **201** and the upper surface of the conductive metal layer **202** may be about 0.43  $\mu\text{m}$  (that is,  $2 \mu\text{m}/\tan 77.7^\circ = 0.43 \mu\text{m}$ ) depending on the maximum angle  $77.7^\circ$  of the reference angle  $\Theta r$ . Accordingly, the length difference **La2** between the upper surface and lower surface of the first conductive metal layer **202** by inclination may be substantially equal to or greater than 0. Therefore, the second angle  $\Theta 2$  of the first conductive metal layer **202** may be smaller than  $90^\circ$ .

When the side wall of the first metal oxide layer **201** protrudes from the side wall of the first conductive metal layer **202** to form the tip **T1**, the second angle  $\Theta 2$  of the sidewall of the first conductive metal layer **202** may be greater than the reference angle  $\Theta r$ . Even in this case, the conductive metal layer **202** and the light reflected thereby may not be viewed by the user.

FIG. **10** is a cross-sectional view showing a first wiring layer and a second wiring layer included in the pixel of FIG. **2** according to an embodiment.

Referring to FIGS. **1**, **2**, **4**, and **10**, a first wiring layer **200** (or a gate wiring **210\_1** and extending portions **232\_1**) is different from the first wiring layer **200** described with reference to FIG. **4** in that it further includes a first intermediate metal layer **203** disposed between the first metal oxide layer **201** and the first conductive metal layer **202**. Similarly, a second wiring layer **500** (or a data wiring **510\_1** and a reference voltage wiring **570\_1**) is different from the second wiring layer **500** described with reference to FIG. **4** in that it further includes a second bonding metal layer **503** disposed between the second metal oxide layer **501** and the second conductive metal layer **502**.

The first intermediate metal layer **203** may include a metal material having an excellent adhesion to the first metal oxide layer **201**, and may be disposed on the first metal oxide layer **201**. For example, the first intermediate metal layer **203** may include a refractory metal having excellent processability. As used herein, the 'refractory metal' refers to a metal or alloy having a melting point higher than  $1500^\circ\text{C}$ . Examples of the refractory metal include niobium (Nb), vanadium (V), tantalum (Ta), titanium (Ti), zirconium (Zr), hafnium (Hf), molybdenum (Mo), and rhenium (Re). For example, the first intermediate metal layer **203** may be a titanium layer including titanium, or may be a single layer including an alloy of titanium. The first intermediate metal layer **203** may exhibit opaque properties.

The second intermediate metal layer **503** is substantially the same as the first intermediate metal layer **203**.

FIGS. **11** and **12** are cross-sectional views showing a first wiring layer and a second wiring layer included in the pixel of FIG. **2** according to embodiments.

Referring to FIGS. **1**, **2**, **4**, **5**, **11**, and **12**, a first wiring layer **200** (or a gate wiring **210\_2** and extending portions **232\_2**) is different from the first wiring layer **200** described with reference to FIG. **4** in that it further includes a first metal oxide layer **201\_2** and a first conductive metal layer **202\_2**. Similarly, a second wiring layer **500** (or a data wiring **510\_2** and a reference voltage wiring **570\_2**) is different from the second wiring layer **500** described with reference to FIG. **4** in that it further includes a second metal oxide layer **501\_2** and a second conductive metal layer **502\_2**.

The first conductive metal layer **202\_2** may be disposed on the first base **110**. The first conductive metal layer **202\_2** may have a laminate structure of two or more layers. For example, the first conductive metal layer **202\_2** may include a first metal layer **202a** and a second metal layer **202b** that are mutually laminated.

The first metal layer **202a** may include a metal material having an excellent adhesion to the first base **110**, and may be disposed directly on the first base **110**. The first metal layer **202a** may be substantially the same as the first intermediate metal layer **203** described with reference to FIG. **10**, except for layout.

The second metal layer **202b** may be disposed directly on the first metal layer **202a**. The second metal layer **202b** may be located on the uppermost layer of the first conductive metal layer **202\_2** having a laminate structure of a plurality of layers. The second metal layer **202b** may be substantially the same as the first conductive metal layer **202** described with reference to FIG. **4**.

In an embodiment, the first metal layer **202a** may be made of a metal material having a refractive index higher than that of the second metal layer **202b**. For example, the refractive index of the first metal layer **202a** to light in the visible light wavelength band may be in a range of 1.5 to 2.8, and the refractive index of the second metal layer **202b** to light in the visible light wavelength band may be in a range of 0.20 to 1.2. For example, the refractive index of the first metal layer **202a** to light having a wavelength of 550 nm may be in a range of 2.3 to 2.6 or about 2.5, and the refractive index of the second metal layer **202b** to light having a wavelength of 550 nm may be in a range of 0.8 to 1.2 or about 1.0.

The thickness **T202b** of the second metal layer **202b** may be greater than the thickness **T202a** of the first metal layer **202a**. For example, the thickness **T202a** of the first metal layer **202a** may be in a range of 5  $\text{\AA}$  to 500  $\text{\AA}$  or in a range of 100  $\text{\AA}$  to 300  $\text{\AA}$ , and the thickness **T202b** of the second metal layer **202b** may be in a range of 1,000  $\text{\AA}$  to 2,000  $\text{\AA}$  or in a range of 5,000  $\text{\AA}$  to 10,000  $\text{\AA}$ .

The side wall of the first metal layer **202a** may protrude beyond the side wall of the second metal layer **202b** to form a tip **T2**. The tip **T2** of the first metal layer **202a** may improve the stability of the second metal layer **202b**. For example, the width **W2a** of the surface of the first metal layer **202a** facing/contacting the second metal layer **202b** may be greater than the width **W2b** of the surface of the second metal layer **202b** facing/contacting the first metal layer **202a**. The length **L2** of the upper side of the tip of the first metal layer **202a** may be about 0.5  $\mu\text{m}$  or less. When the length **L2** of the tip **T2** is greater than 0.5  $\mu\text{m}$ , the leakage current (off current) of a switching element may remarkably, undesirably increase.

The first metal oxide layer **201\_2** may be a single layer disposed directly on the second metal layer **202b**. The first metal oxide layer **201\_2** may include a material having

larger light absorbance and smaller light reflectance than the first conductive metal layer **202\_2**. The first metal oxide layer **201\_2** may have larger light absorbance and smaller light reflectance than each of the first metal layer **202a** and the second metal layer **202b**. The first metal oxide layer **201\_2** may be substantially the same as the first metal oxide layer **201** described with reference to FIG. 4.

In an embodiment, the first metal oxide layer **201\_2** may include  $\text{Mo}_x\text{Ta}_y\text{O}_z$ .

The content of tantalum in the metal atoms in the first metal oxide layer **201\_2** may be about 20.0 at % (atomic percent) or less, about 12 at % or less, or about 2 at % or less. That is, the uppermost of the ratio  $(y/(x+y))$  of  $y$  to  $(x+y)$  may be about 0.20. When the content of tantalum is greater than 20 at %, etching stability deteriorates, and thus it is difficult to control an etching surface. For example, the tip T1 of the first metal oxide layer **201\_2** may become excessively long.

As the content of tantalum increases, the light reflectance of the first metal oxide layer **201\_2** to the visible light wavelength band may increase as described with reference to FIG. 7.

In an embodiment, the sidewall of the first metal oxide layer **201\_2** may protrude beyond the sidewall of the second metal layer **202b** to form a tip T1. The tip T1 of the first metal oxide layer **201\_2** may contribute to a decrease in the reflectance on the upper side of the first wiring layer **200\_2**. For example, the width W1a of the surface of the first metal oxide layer **201\_2** facing/contacting the second metal layer **202b** may be greater than the width W1b of the surface of the second metal layer **202b** facing/contacting the first metal oxide layer **201\_2**. The length L1 of the lower side of the tip T1 of the first metal oxide layer **201\_2** may be about 0.80  $\mu\text{m}$  or less. When the length L of the tip T1 is greater than 0.80  $\mu\text{m}$ , the subsequent processability after forming the first wiring layer **200\_2** may be deteriorated. For example, when the length L1 of the tip T1 of the first metal oxide layer **201\_2** is less than 0.80  $\mu\text{m}$ , the film compactness of the first insulating layer **310** may be improved. Further, the length L of the tip may be about 0.03  $\mu\text{m}$  or more. When the length L1 of the tip T1 of the first metal oxide layer **201\_2** is greater than 0.03  $\mu\text{m}$ , it may be effective to reduce the reflectance of the first wiring layer **200\_2**.

The first metal oxide layer **201\_2** may be located at the uppermost layer of the first wiring layer **200**. The first metal oxide layer **201\_2** having its own high light absorbance and having a destructive interference thickness, so that the reflectance of the first wiring layer **200** to the light EXL incident from above may be effectively reduced. In embodiments, the reflectance of the first wiring layer **200\_2** to the light EXL having a wavelength of 550 nm incident from the side of the first metal oxide layer **201\_2** toward the first wiring layer **200\_1** may be about 6.0% or less, about 5.5% or less, about 5.4% or less, about 5.3% or less, about 5.2% or less, about 5.1% or less, or about 5.0% or less. Since the first wiring layer **200\_1** includes the first conductive metal layer **202\_2**, it may provide excellent electrical conductivity and may function as a wiring and an electrode.

The second wiring layer **500\_2** may be substantially the same as the first wiring layer **200\_2**, except that it is disposed on the first insulating layer **310** and the active layer **400**.

The first wiring layer **200\_2** and the second wiring layer **500\_2** may have very low reflectance with respect to the visible light wavelength band, so that the planar area occu-

ried by the light blocking member **700** may be minimized, and thus the aperture ratio of the display device may be maximized.

The display device according to the embodiments includes a wiring layer including molybdenum oxide ( $\text{MoO}_x$ ,  $\text{Mo}_x\text{Ta}_y\text{O}_z$ ) having very low reflectance for a visible light wavelength band, thereby minimizing deterioration of display quality potentially caused by reflection of external light. The second wiring layer **500\_2** may be substantially the same as the first wiring layer **200\_2**, except that it is disposed on the first insulating layer **310** and the active layer **400**. The second conductive metal layer **502\_2** may be disposed on the active layer **400**. The second conductive metal layer **502\_2** may have a laminate structure of two or more layers. For example, the second conductive metal layer **502\_2** may include a first metal layer **502a** and a second metal layer **502b** that are mutually laminated. The second metal layer **502b** may be disposed directly on the first metal layer **502a**. The second metal layer **502b** may be located on the uppermost layer of the second conductive metal layer **502\_2** having a laminate structure of a plurality of layers. The second metal layer **502b** may be substantially the same as the second conductive metal layer **502** described with reference to FIG. 4.

In an embodiment, the first metal layer **502a** may be made of a metal material having a refractive index higher than that of the second metal layer **502b**. For example, the refractive index of the first metal layer **502a** to light in the visible light wavelength band may be in a range of 1.5 to 2.8, and the refractive index of the second metal layer **502b** to light in the visible light wavelength band may be in a range of 0.20 to 1.2. For example, the refractive index of the first metal layer **502a** to light having a wavelength of 550 nm may be in a range of 2.3 to 2.6 or about 2.5, and the refractive index of the second metal layer **502b** to light having a wavelength of 550 nm may be in a range of 0.8 to 1.2 or about 1.0.

The thickness T502b of the second metal layer **502b** may be greater than the thickness T502a of the first metal layer **502a**. For example, the thickness T502a of the first metal layer **502a** may be in a range of 5 Å to 500 Å or in a range of 100 Å to 300 Å, and the thickness T502b of the second metal layer **502b** may be in a range of 1,000 Å to 2,000 Å or in a range of 5,000 Å to 10,000 Å.

The second metal oxide layer **501\_2** may be a single layer disposed directly on the second metal layer **502b**. The second metal oxide layer **501\_2** may include a material having larger light absorbance and smaller light reflectance than the second conductive metal layer **502\_2**. The second metal oxide layer **501\_2** may have larger light absorbance and smaller light reflectance than each of the first metal layer **502a** and the second metal layer **502b**. The second metal oxide layer **501\_2** may be substantially the same as the second metal oxide layer **501** described with reference to FIG. 4.

In an embodiment, the sidewall of the second metal oxide layer **501\_2** may protrude beyond the sidewall of the second metal layer **502b** to form a tip T3. The tip T3 of the second metal oxide layer **501\_2** may contribute to a decrease in the reflectance on the upper side of the second wiring layer **500\_2**. For example, the width W3a of the surface of the second metal oxide layer **501\_2** facing/contacting the second metal layer **502b** may be greater than the width W3b of the surface of the second metal layer **502b** facing/contacting the second metal oxide layer **501\_2**. The length L3 of the lower side of the tip T3 of the second metal oxide layer **501\_2** may be about 0.80  $\mu\text{m}$  or less. When the length L3 of the tip T3 is greater than 0.80  $\mu\text{m}$ , the subsequent process-

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ability after forming the second wiring layer **500\_2** may be deteriorated. For example, when the length **L3** of the tip **T3** of the second metal oxide layer **501\_2** is less than 0.80  $\mu\text{m}$ , the film compactness of the protective layer **331** may be improved. Further, the length **L3** of the tip may be about 0.03  $\mu\text{m}$  or more. When the length **L3** of the tip **T3** of the second metal oxide layer **501\_2** is greater than 0.03  $\mu\text{m}$ , it may be effective to reduce the reflectance of the second wiring layer **500\_2**.

In embodiments, since the reflectance of the wiring layer itself is very low, the planar area occupied by a light blocking member can be minimized, so that the aperture ratio of the display device can be maximized, and the resolution of the display device can be further improved.

Although example embodiments have been disclosed for illustrative purposes, those skilled in the art will appreciate that various modifications, additions, and substitutions are possible without departing from the scope defined in the accompanying claims.

What is claimed is:

1. A display device, comprising:

a first base;

a metal oxide layer overlapping a face of the first base;

a semiconductor material layer spaced from the metal oxide layer; and

a conductive metal layer directly contacting the metal oxide layer and spaced from the semiconductor material layer,

wherein the metal oxide layer includes molybdenum oxide and protrudes beyond the conductive metal layer in a direction parallel to the face of the substrate,

wherein a side of the metal oxide layer is oriented at a first angle relative to the face of the first base,

wherein a side of the conductive metal layer is oriented at a second angle relative to the face of the first base, and wherein a size of the second angle is in a range of 30° to 75°.

2. The display device of claim 1,

wherein a light reflectance of the metal oxide layer is lower than a light reflectance of the conductive metal layer.

3. The display device of claim 2,

wherein a first wiring layer of the display device comprises the metal oxide layer and the conductive metal layer, and

wherein a light reflectance of the first wiring layer to light having a wavelength of 550 nm incident from the face of the first base is 6.0% or less.

4. The display device of claim 3,

wherein a maximum thickness of the metal oxide layer in a direction perpendicular to the face of the first base is in a range of 100 Å to 2000 Å.

5. The display device of claim 1,

wherein the conductive metal layer includes a first metal layer and a second metal layer,

wherein the first metal layer is disposed between the metal oxide layer and the second metal layer, and

wherein the second metal layer has higher electrical conductivity than the first metal layer.

6. The display device of claim 5,

wherein a first wiring layer of the display device comprises the metal oxide layer and the conductive metal layer, and

wherein a light reflectance of the first wiring layer to light having a wavelength of 550 nm incident from the face of the metal oxide layer is 6.0% or less.

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7. The display device of claim 1,

wherein the conductive metal layer includes a first metal layer and a second metal layer, and

wherein the second metal layer is disposed between the first metal layer and the metal oxide layer and has higher electrical conductivity than the first metal layer.

8. The display device of claim 7,

wherein a maximum thickness of the metal oxide layer in a direction perpendicular to the face of the first base is greater than a maximum thickness of the first metal layer in the direction perpendicular to the face of the first base and is smaller than a maximum thickness of the second metal layer in the direction perpendicular to the face of the first base.

9. The display device of claim 8,

wherein the maximum thickness of the metal oxide layer in the direction perpendicular to the face of the first base is in a range of 100 Å to 2000 Å.

10. The display device of claim 7,

wherein the first metal layer includes a refractory metal, and

wherein the second metal includes at least one of copper and silver.

11. The display device of claim 7,

wherein a first face of the first metal layer and a first face of the second metal layer are positioned between a second face of the first metal layer and a second face of the second metal layer, and

wherein the first face of the first metal layer is wider than the first face of the second metal layer in the direction parallel to the face of the first base.

12. The display device of claim 7,

wherein the metal oxide layer directly contacts a face of the conductive metal layer and protrudes beyond the face of the conductive metal layer in the direction parallel to the face of the first base.

13. The display device of claim 1,

wherein a side of the conductive metal layer is oriented at an angle relative to the face of the first base and directly contacts a portion of a flat side of the metal oxide layer, wherein the portion of the flat side of the metal oxide layer is positioned between two opposite sides of the metal oxide layer and is positioned between two opposite edges of the flat side of the metal oxide layer,

wherein each of the two opposite sides of the metal oxide layer is directly connected to the flat side of the metal oxide layer,

wherein the face of the first base is equidistant from the two opposite sides of the metal oxide layer, and

wherein a size of the angle is in a range of 30° to 75°.

14. A display device, comprising:

a first base;

a metal oxide layer overlapping a face of the first base;

a semiconductor material layer overlapping the metal oxide layer and spaced from the metal oxide layer; and

a conductive metal layer directly contacting the metal oxide layer and spaced from the semiconductor material layer,

wherein the metal oxide layer includes molybdenum oxide,

wherein a side of the metal oxide layer is oriented at a first angle relative to the face of the first base,

wherein a side of the conductive metal layer is oriented at a second angle relative to the face of the first base,

wherein a size of the second angle is in a range of 30° to 75°, and

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wherein the metal oxide layer is disposed directly on the first base and disposed between the conductive metal layer and the first base.

15. The display device of claim 14, wherein the first angle is smaller than the second angle. 5

16. The display device of claim 15, wherein the size of the second angle is in a range of 45° to 70°.

17. The display device of claim 14, wherein the metal oxide layer directly contacts a face of the conductive metal layer and protrudes beyond the face of the conductive metal layer in a direction parallel to the face of the first base. 10

18. The display device of claim 14, wherein the metal oxide layer further includes tantalum, and wherein a content of the tantalum in metal atoms is in a range of 0.5 at % to 12 at % in the metal oxide layer. 15

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19. The display device of claim 14, wherein the conductive metal layer includes a first metal layer and a second metal layer, wherein the first metal layer is disposed between the metal oxide layer and the second metal layer, and wherein the second metal layer has higher electrical conductivity than the first metal layer.

20. A display device, comprising:  
 a first base;  
 a conductive metal layer overlapping a face of the first base; and  
 a metal oxide layer directly contacting the conductive metal layer,  
 wherein the metal oxide layer includes  $Mo_xTa_yO_z$ ,  
 wherein a side of the conductive metal layer is oriented at an acute angle relative to the face of the first base, and  
 wherein a content of tantalum in metal atoms is in a range of 0.5 at % to 20 at % in the metal oxide layer.

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